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Life cycle cost analysis and payback period of lighting retrofit at the University of Malaya

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A R T I C L E I N F O

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A B S T R A C T

This study presents the potential energy saving, life cycle cost analysis and payback period of the lighting system in campus buildings of the University of Malaya, Malaysia. The survey results indicate that almost 90% of the lighting system at the University Malaya campus consists of fluorescent lamp. Cost benefit analysis of retrofitting with more efficient lighting system in terms of potential energy saving, life cycle cost analysis and payback period have been conducted. Comparison of existing and retrofitting of lighting system based on the energy consumption is presented. From the analysis, it can be concluded that by using energy efficient lighting system will save a significant amounts of energy and cost, and also indirectly reducing emission.

Contents

1. Introduction

Lighting system is essential to ensure the comfort, productivity and safety of the occupants in the buildings. Therefore, the lighting system needs to be correctly designed to achieve the desired illumination level while using minimum amount of electricity. Lighting accounts for up to one third of an office building's electricity consumption. Rational use of electricity within buildings is a very important and relevant subject especially when energy is increasingly becoming more expensive and excessive use of it may cause climate change through high emissions of greenhouse gases [1].

Increase in energy consumption has negative impact on the environment, therefore the policy to use energy efficiently should be proposed. Some of the works related to potential energy savings,

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Nomenclature

LCC	Life cycle cost (RM)
EC	Energy consumption (kW h)
N	Number of lamp
OH	Operating hour (h)
PP	Payback period (year)
IC	Investment cost (RM)
PC	Purchase cost (RM)
PWF	Present worth factor
ET	Electricity tariff (RM/kW h)
OC	Operating cost (RM)
BS	Bill savings (RM)
ES	Energy savings (RM)
ER_i^L	Emission reduction for a unit electricity generation (kg, ton)
EM_p^n	Emission for a unit electricity generation of fuel type *n* (kg)
PE_i^n	Percentage of electricity generation in year *i* of fuel type *n* (%)

cost savings and emission reductions in Malaysia is given by Refs. [2–13]. While the paper specifically deal with projected electricity savings, cost-benefit analysis and emission reduction of lighting retrofit for residential buildings in Malaysia in given by Ref. [14]. The cost-benefit is determined as a function of energy savings by retrofitting with more efficient lighting system. The energy savings were calculated based on 25%, 50% and 75% of potential retrofits of inefficient lighting in residential sector. It was concluded that by adopting this strategy a significant amount of energy and money could be saved. The similar topic about the potential to improve the energy efficiency of lighting systems at Melbourne University [15]. The cost effectiveness of different lighting technology was calculated and the energy consumption of existing 1.2 m fluorescent lighting fixtures and four energy efficient lighting technology as an alternative was compared. The study found that by installing four lighting technology would result in 13.9%, 20.5%, 24.4% and 64.9%, energy savings respectively.

The major electricity used in educational building was lighting system, it consume almost 42% of total energy. By means of reducing the energy consumption by lighting system already enough to reduce cost. Percentage energy used in educational building is presented in Fig. 1.

The continuing shortfall between electricity demand and supply, the increasing cost of building new power plants and competing needs for investment capital are main reasons to encourage all consumers to choose the energy efficiency technology which give more benefits. University of Malaya also wanted to be one of the green campuses by improving energy efficiency in all aspect. University of Malaya, or UM, Malaysia's oldest university, is situated on a 309 hectare (750 acre) campus in the southwest of Kuala Lumpur, the capital of Malaysia. The map of the campus showing the building and the road inside the campus is prosecuted in Fig. 2. There are 447 blocks with total floor are 712,846 m^2 in the campus.

This study attempts to calculate potential energy savings and life cycle cost analysis by applying energy efficiency lighting system in the University of Malaya.

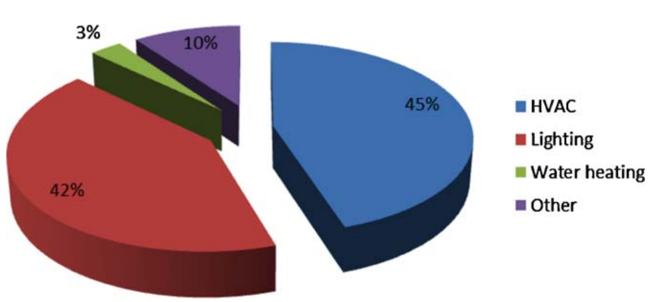

Fig. 1. Percentage energy used in educational building.

2. Data collection

2.1. Lighting system overview

Many types of lighting system are available in the market but the selection of the lamp depends on the type of task that will be accomplished by the lamp and some properties of the lamp. Incandescent lamps generate light from incandescent filament confined inside the inert environment of the glass bulb. Presently this type of lamp has been slowly phased out due to their low efficacy. The most common type of lamp used today is fluorescent lamp. A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light. A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp [26].

Fluorescent light bulbs come in many shapes and sizes. They are identified by a standardized coding system that reveals valuable information about operating characteristics and physical dimensions. One key factor is a tube's diameter, and this is given by the number following a '*T*' (which denotes 'tubular'), refers to the tube's diameter, so, for example, a T8 tube would have a diameter of 1 inch [27]. Available energy efficient lighting technology alternative is given in Table 1. Table 2 present few types of lamp and their key performance indices. Various type of lamp has been installed in the University of Malaya, however almost 90% of the lighting system is fluorescent lamp. The alternative lightings considered in this study are high performance T8 and T5 fluorescent. The relative diameter of popular linear fluorescent lamps is presented in Fig. 3 [27].

This study also includes T5 fluorescent lamp, which is alternative to T8 and T12, an energy efficient option for fluorescent lighting system. The new T5 are 16mm wide and 40% can be smaller than T8 systems. The use of T5 system requires electronic ballast with high efficiency version that can reach a lamp luminous efficacy of more than 100 lm/W. T5 fluorescent lamp converter with built in ballast is presented in Fig. 4 [27]. T5 systems created by manufacturers compete in the compact fluorescent lighting market. T5 fluorescent lamp is energy efficient that reduces energy consumption of power about 50% while still providing the same light output as regular fluorescent lights.

The retrofitting systems can involve many or few component. Standard T8 system have been installed in campus since 10 years ago using 36 W and 18 W with electronic ballast. To reduce light-

Table 1
Energy efficiency lighting technology alternatives.

Lighting technology alternatives	
T8 magnetic	Existing fixtures using T8 system with 18 W and 36 W bulb with magnetic ballast
T8 electronic	Existing fixtures using T8 system with 18 W and 36 W bulb with electronic ballast
HPT8 electronic	Existing fixtures are replaced with 17 W and 32 W bulb with electronic ballast
T5 electronic	Existing fixtures are replaced with new conversion kits built in ballast with 14 W and 28 W bulb

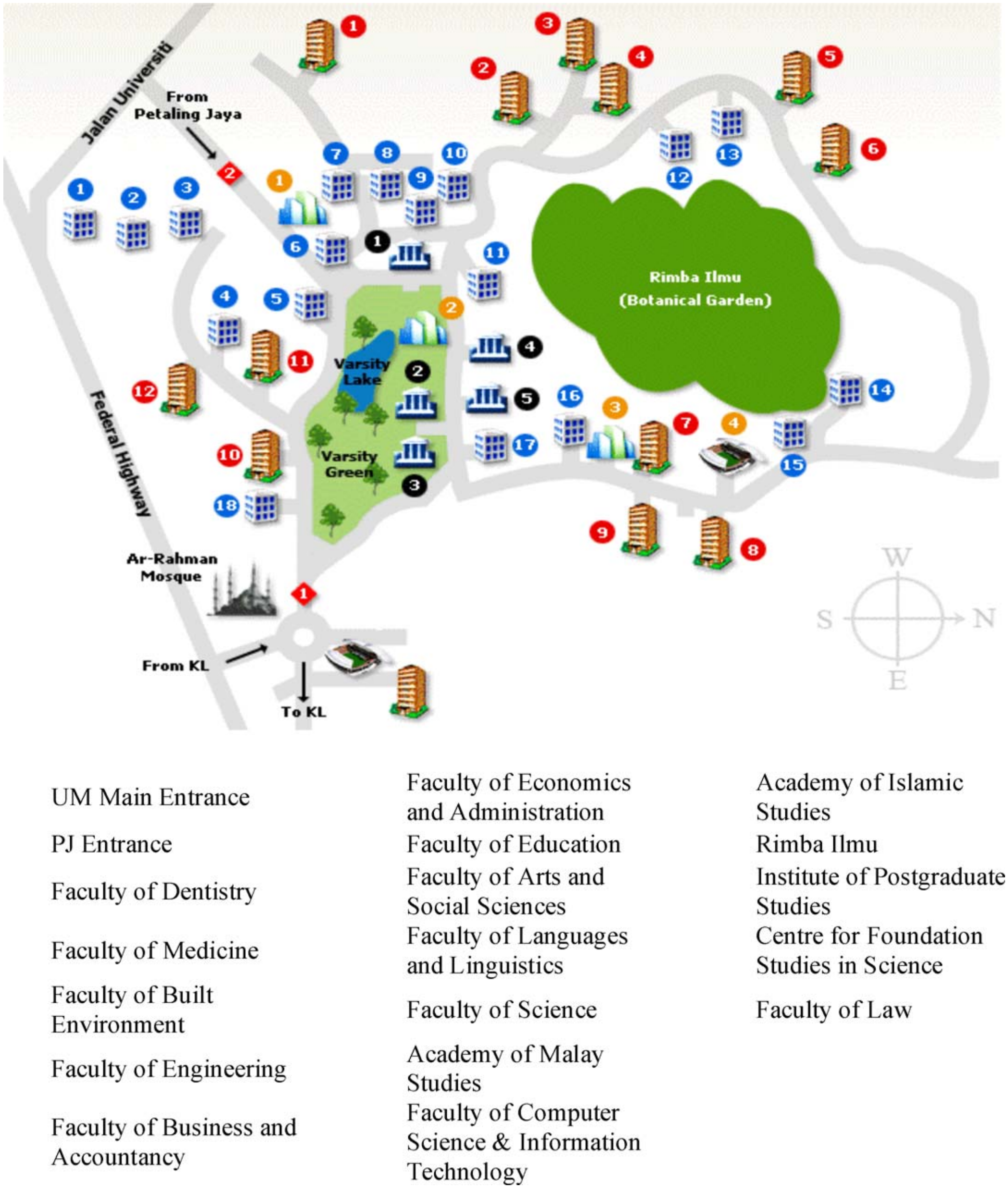

Fig. 2. Map of the University of Malaya campus.

ing energy costs, T8 fluorescent lamps with electronic ballast have become the standard for new fixtures and retrofits in buildings. New products, energy efficient lighting technology proven by practical experience, achieve a balance between optimum lighting and energy cost and savings.

First alternative is replacing the electromagnetic ballast with electronic ballast to the old system. The second alternative proposed is to reduce wattage by Converting T8 bulbs, which is old generation that goes from T8 18 W and 36 W down to T8 17 W and 32 W. This retrofitting only required small investment to change the bulb. The third alternatives is retrofitting old system to new T5 adapter which converts energy guzzling T8 bulbs to new T5 energy saving. It only just clips into the existing fixture and take out the starter. This adapter feature already built in ballast. This adapter allows the end user the ability to retrofit from T8 system without changing the fixture. With a simple rewiring, it will produce better, efficient lighting and bill saving at the same time. Even though, T5 adapter requires high installation cost it can save more energy and

Table 2
Typical value of performance indices of different lighting system [37,38].

Lamp	Lamp wattage (W)	Lumens	Efficacy (lm/W)	Color temperature (K)	Color rendering index
Incandescent lamp	75	950	10–15	2,600–3,000	100
Compact fluorescent lamp	15	810	50–60	5,000–6,000	64–73
Fluorescent lamp	36	2,400	69–100	3,200–7,500	80–95
High-pressure sodium lamp	100	10,500	80–140	2,000–3,200	25
Low-pressure sodium lamp	131	26,000	150–200	1,600	0

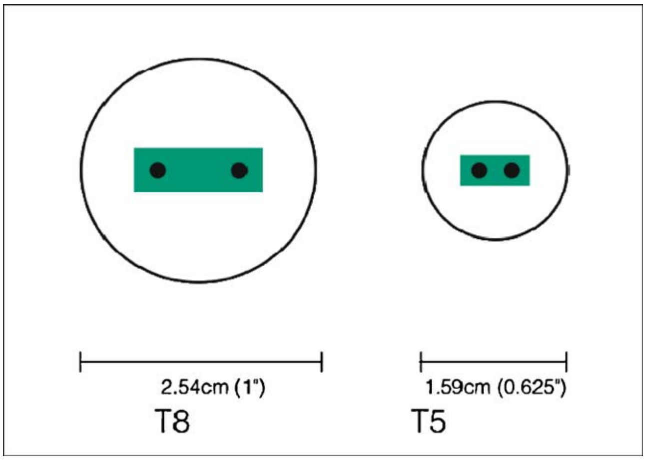

Fig. 3. The relative diameter of popular linear fluorescent lamps [27].

Fig. 4. T5 fluorescent lamp converter with built in ballast [27].

time compares to the alternative 1 and 2. Alternative lamp type and price is given in Table 3.

T8 is to replaces the old T12 fluorescent lamp without any modification of the fixture. T8 refer to 1-inch or 26 mm diameter fluorescent lamp. T8 fluorescent lamps with electronic ballast have become the standard for new fixtures and retrofits in commercial office buildings, schools, and a substantial portion of industrial lighting. T8 fluorescent lamp required electronic ballast to operate either rapid start electronic ballast or instant start electronic ballast. T8 fluorescent lamps require electronic ballast that is designed specifically to operate lamps at a lower current than T12 lamps. When T12 lamps are replaced with T8 lamps, therefore, the ballast must also be replaced. The advantage of electronic ballasts is that they do not flicker or hum and they use less energy than conventional ballasts.

Table 3
Alternative lamp type and price.

Type	Alternatives	600 mm	1200 mm
		Price	Price
Bulb	T8 electronic	–	–
Ballast		RM 22	RM 25
Total		RM 22	RM 25
Bulb	HPT8 electronic	RM10.9	RM 12.9
Ballast		RM 22	RM 25
Total		RM 32.9	RM 37.9
Conversion kits	T5 Electronic	RM 38.5	RM 53.5

The new T5 are 16 mm in diameter will reduce energy consumption by about 50% while providing the same light output as regular fluorescent lights. T5 light tube can last at least 18,000 h with 5% reduction of output in its life. A T8 light tube usually lasts about 20,000 h but it loses about 20% output in its life. Initial cost of installment of T5 is more than T8 but this is offset by the energy saving for long period. To retrofit the existing system with T5 an additional conversion kit is necessary for installation.

The light output of T5 fluorescent lamps per unit length is almost identical to the larger T8 lamps. T5 lamps cannot be used as replacements for T8 lamps as they are slightly shorter. However, some luminaries can be adapted to accept either T5 or T8 lamps by changing the sockets and ballasts. T5 is a versatile and effective sources of illumination that is ideal for factories, schools, offices, supermarkets, underground railways etc [27]. Properties of T8 and T5 lamps of length 1200 mm and 600 m are presented in Tables 4 and 5.

Standard T8 system has been installed in the UM campus since 10 years ago using 36 W and 18 W with electronic ballast. To replace lighting systems that expired after the end of lamp life. The study proposes a reduction of wattage by retrofitting of T8 standard fluorescent lamp with more efficient high performance T8 lighting system (HPT8) and T5 fluorescent lamp in the University of Malaya. The input wattage has been used are standardized by ANSI C.78 reference standard given in Table 6.

2.2. Survey data

A survey is necessary to determine the saturation level of inefficient lighting, the operating hours of the lamp and the number of potential retrofit of the lighting system in the every building in the university. Survey has been conducted on each room of each block in the campus. The data that have been collected include the number of lighting fixtures and operating hours. The length of tube of fluorescent lamp surveyed in this study was 600 mm and 1200 mm with 18 W and 36 W respectively. This study only focuses on fluorescent lamp especially fluorescent fixtures, globes and ballast. The

Table 4
Lighting properties comparison of T8 and T5 for 1200 mm.

Lamp type	Ballast	Ballast factor	Lumens (lm)	Lifetime (h)	Cost (RM)
Standard T8 36 W	Electronic	0.98	3350	20,000	6.9
HPT8 32 W	Electronic	0.88	2800	24,000	8.5
T5 28 W (1149 mm)	Electronic	0.95	2900	18,000	10.9

Table 5
Lighting properties comparison of T8 and T5 for 600 mm.

Lamp type	Ballast	Ballast factor	Lumens (lm)	Lifetime (h)	Cost (RM)
Standard T8 18 W	Electronic	0.98	1500	20000	5.9
HPT817 W	Electronic	0.88	1325	24000	7.7
T5 14 W (549 mm)	Electronic	0.95	1350	18000	9.5

Table 6
The Input wattage.

Bulbs	Wattage	No. of lamps	System power (W)	
			Magnetic ballast	Electronic ballast
T8	18 W	1	24	18
		2	46	35
		3	69	54
	36 W	1	43	35
		2	82	71
		3	122	110
HPT8	17 W	1		20
		2		34
		3		47
	32 W	1		28
		2		58
		3		82
T5	14 W	1		14
		2		26
		3		42
	28 W	1		25
		2		52
		3		78

names of the building, institute and faculty and the number of lamp are shown in Table 7. The data obtained from the survey was used to calculate projected electricity savings and life cycle cost analysis of lighting retrofits.

In Malaysia the electricity tariff is RM0.281/kW h. In this study assumed that the electricity tariff increase about 2% every year.

3. Methodology

3.1. Electricity consumption

The electricity consumption by the existing fluorescent was estimated for whole campus based on the survey conducted. The total energy consumption (EC) of lighting system is determined by multiplying the number of lamp (N), power (W) used per fixtures and the operating hour (OH) of the lighting. The annual energy consumption for existing lighting system was calculated based on the following equation [15]:

$$EC = \frac{N \times W \times OH}{1000} \tag{1}$$

According to the retrofitting studies, the energy consumption should be calculated based on how much the lighting fixtures wanted to be replace. Retrofitting starting at 10–100% as retrofitting from old system. The results for single, double or triple fixtures were summed to find a total wattage value for each room.

3.2. Energy savings

Energy saving (ES) is the difference between energy consumption of existing (EC_{Existing}) and retrofit lighting ($EC_{\text{Retrofiting}}$) system. The following equation was used to calculate energy savings.

$$ES = EC_{\text{Existing}} - EC_{\text{Retrofitting}} \tag{2}$$

3.3. Bill savings

Bill saving (BS) was calculated by multiplying energy saving with electricity tariff (ET), Electricity tariff is assumed to be increase about 2% every year. This is can be calculated by the following equation:

$$BS = ES \times ET \tag{3}$$

3.4. Operating cost

Operating cost (OC) is the cost needed for new retrofit system, which is a total number of lamps (N), multiply by watt consumed (W), operating hours (OH) and electricity tariff (ET) and this can be calculated by the following equation:

$$OC = N \times W \times OH \times ET \tag{4}$$

3.5. Present worth factor

Present worth factor (PWF) is the value by which future cash flow to be received in order to obtain the current present value. The present worth factor can be calculated by the following equation:

$$PWF = \sum_{1}^{N} \frac{1}{(1+r)^t} = \frac{1}{r}\left[1 - \frac{1}{(1+r)^N}\right] \tag{5}$$

3.6. Payback period

The payback period (PAY) measures the amount of time needed to recover the additional investment (increment cost) (ΔPC) on effi-

Table 7
Number of lamps collected.

Faculty	Single globe		Double globe		Triple globe	
	600 mm	1200 mm	600 mm	1200 mm	600 mm	1200 mm
AAJ	13	1334				
API	3287	1938		818		
APM	1338	1653				
FBL	315	1964				
FEP	1552	1828	42	131		
FK	1085	6682		1289		
FP	98	293	440	989		
FPP	168	844		155		
FScn	134	901	369	4093	406	427
FSSS	140	3709				
FU	131	327	114	1211		
PASUM	200	2058				
PS	120	845		86		
UMLib	418	5949				
FAB	145	56	59	819		
FSK	287	2029		128		
Total						53417

*Average operating hours: 10 h/day.

ciency improvement through lower operating costs. *PAY* is found by solving the following equation:

$$\Delta PC + \sum_{1}^{PAY} \Delta OC_t = 0 \quad (6)$$

In general, *PAY* is found by interpolating between the two years when the above expression changes sign. If the *OC* is constant, the equations has the following solution [39]:

$$PAY = -\frac{\Delta PC}{\Delta OC} \quad (7)$$

The *PAY* is the ratio of the incremental cost (from the baseline to the more efficient product) to the decrease in annual operating cost. If *PAY* is greater than the lifetime of the product, it means that the increased purchase price is not recovered in reduced operating cost.

3.7. Life cycle cost

A life cycle cost (*LCC*) analysis calculates the cost of a system or product over its entire life span. For this study *LCC* is used to calculate the cost of energy efficiency improvement of the lighting system based on design option. The *LCC* is the sum of investment cost (*PC*) and the annual operating cost (*OC*) discounted over the lifetime of the product. *LCC* is calculated by the following equation [10]:

$$LCC = PC + \sum_{1}^{N} \frac{OC_t}{(1-r)^t} \quad (8)$$

If operating expenses are constant over time, the *LCC* is simplified to the following equations:

$$LCC = PC + (PWF)(OC) \quad (9)$$

4. Results and discussion

4.1. Energy consumption

The calculation results for energy consumption, potential energy saving, bill savings and payback period is presented in this section. Electricity tariff is RM 0.281/kW h in Malaysia and 2% increase of tariff is assumed every year according to market price for fossil fuel to generate electricity. Energy saving and bill saving was calculated for existing, HPT8 and T5 fluorescent lamp. The energy savings and bill savings increases with the increase of retrofitting due to the higher efficiency of HPT8 and T5 lamps. The energy consumption decreases 12% if 100% of the existing lighting system is replaced by HPT8 lighting system and decreases 23% if the total number of existing lighting system is replaced by T5 lighting system. Using efficient lighting system such as HPT8 and T5 can save the cost 13.5% and 27% respectively.

To calculate energy consumption and potential energy saving using efficiency lighting retrofits, it is necessary to have the daily average operating hour and number of lamp. In data collected by survey, average operating hour per day is about 10 h and operate only 5 days per week. By using new energy efficiency technology and by the information given in Table 2.4, potential energy savings can be calculated. For the first one year, 10% retrofit have been estimate to replace the standard with T8 electronic, HPT8 and T5 system continuously for 10 years until it reaches 100% retrofitting. From the calculation of energy savings, it shows that retrofit the existing system using T8 electronic system, HPT8 system and T5 system can reduce the energy consumption up to 17%, 31% and 40% respectively at 100% retrofitting.

Table 8
Energy consumption between standard and new alternative.

Year	Energy consumption (kW)			
	Existing T8	T8 electronic	HPT8	T5
2012	6,609,158	6,609,158	6,609,158	6,609,158
2013	6,609,158	6,493,954	6,402,908	6,344,325
2014	6,609,158	6,378,750	6,196,658	6,079,491
2015	6,609,158	6,263,545	5,990,407	5,814,658
2016	6,609,158	6,148,341	5,784,157	5,549824
2017	6,609,158	6,033,137	5,577,907	5,284,991
2018	6,609,158	5,917,933	5,371,657	5,020,158
2019	6,609,158	5,802,729	5,165,407	4,755,324
2020	6,609,158	5,687,525	4,959,156	4,490,491
2021	6,609,158	5,572,320	4,752,906	4,225,657
2022	6,609,158	5,457,116	4,546,656	3,960,824

By replacing magnetic ballast with electronic ballast to the existing system it can reduce the energy consumption to and lower operating costs. The electronic ballasts are more efficient compare to magnetic ballasts in converting input power to the proper lamp power. Besides that, the ballast operates the fluorescent lamps at higher frequencies that reduce end losses, resulting in increasing efficiency an overall lamp ballast system. Using a single ballast to drive three or four lamps, instead of only one or two, may also reduce ballast losses.

Energy consumption using T8 electronic system with the standard 18 W and 36 W bulb can reduce the energy about 17% compare to the standard system. Every year, University of Malaya spends RM 2,304,167 (1USD = RM3.3) per year to pay the utility for lighting system and now UM only need to pay RM 1,902,528 per year if the retrofitting is 100% done.

For the second alternative using high performance T8 system which is using T8 17 W and 32 W bulb operate with electronic ballast also reduce large amount of energy compare to the T8 electronic. By comparing with the standard system, it can reduce about 31% energy consumption. The operating cost will also reduce to RM 1,585,112 even lower than T8 electronic.

For the third alternative using T5 system show the most energy reduce compare to the two alternatives discussed above. This is because the size of the bulb and the wattage has been reduced meanwhile it can produce same amount of light as standard lighting system. It also operates with electronic ballast, which is specially designed together with their converter. The energy reduces up to 40% from the existing system. That gives enough impact to user to see the difference between the alternatives shown. The operating costs reduce to RM 1,380,872 lower than the two alternatives.

Table 8 shows the energy compliance of the system is 6,609,158 kW h per year. Every year, 10% retrofits have been estimate to replace with new energy efficiency technology system continuously for 10 years. It also show that total energy consumed at the end of year 2022 decrease more than previous year because 100% existing lighting system have been replaced with energy efficiency lighting system.

Instead of table given, this data also presented in graph shown in Figs. 5–8. From the figure can see the relation between the payback period and life cycle cost.

Table 9 show amount of bill saving based on the 10% retrofit every year until 100% done by comparison between existing and new energy efficiency technology, which approach by the energy savings. It shows the amount that save every year as effect from retrofitting by 10% every year.

4.2. Payback period and life cycle cost

Payback period is a tool to determine time required to recover an investment. Payback period is important for financial management

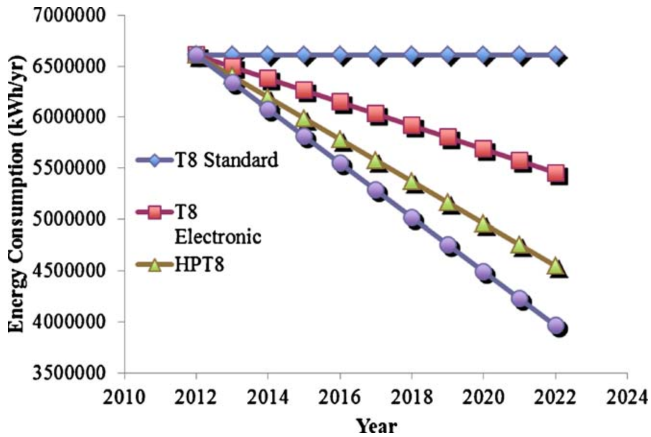

Fig. 5. Comparison energy consumption between existing and after new retrofit system.

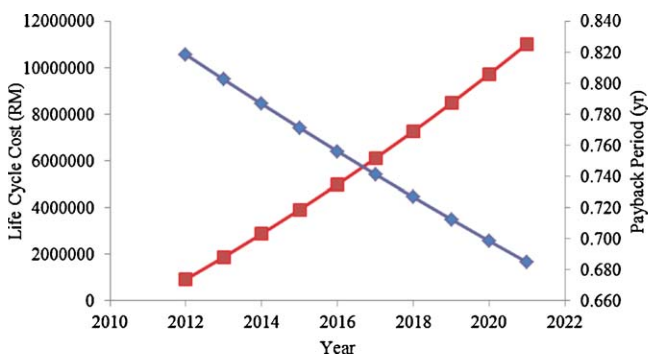

Fig. 6. Impact of using T8 electronic lighting system to payback period and life cycle cost.

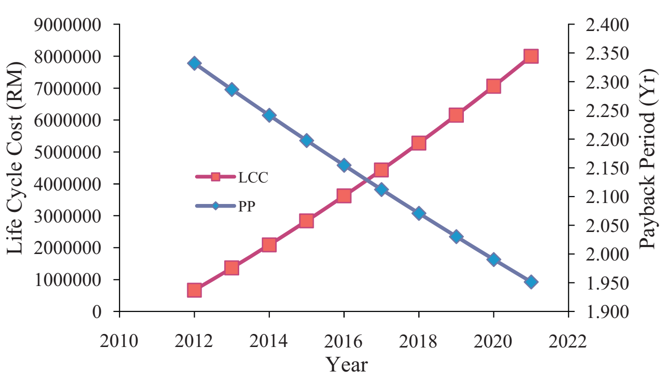

Fig. 7. Impact of using HPT8 lighting system to payback period and life cycle.

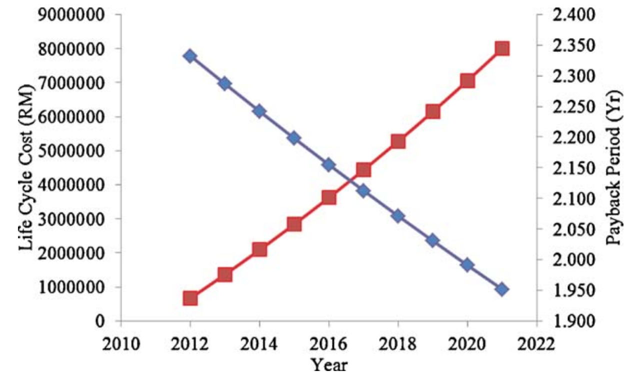

Fig. 8. Impact of using T5 lighting system to payback period and life cycle cost.

Table 9
Bill savings summary for every year according to the percentage retrofit.

Year	Bil savings (RM)		
	T8 electronic	HPT8	T5
2012	0	0	0
2013	33,607	60,167	77,257
2014	68,559	122,741	157,605
2015	104,895	187,794	241,135
2016	142,658	255,400	327,944
2017	181,888	325,635	418,128
2018	222,631	398,577	511,789
2019	264,931	474,307	609,029
2020	308,834	552,907	709,954
2021	354,387	634,460	814,672
2022	401,639	719,055	923,295
TOTAL	2,084,031	3,731,044	4790,808

to look whether the investment made giving a proper recover time. Cost is total energy cost consume by retrofit system. And in the graph of LCC and PP for each retrofitting is presented in Figs. 6–8.

Among of the three alternatives, cost for retrofitting the existing system to T5 system required large amount of investment since it almost replaces all of the lighting system accept fixtures. Cost for T5 system is slightly higher because of T5 fluorescent tube is expensive and need extra cost for conversion kit. It followed by HPT8 that required cost for replace the bulb and ballast. For the T8 electronic, cost needed only for replace the ballast from magnetic ballast to electronic ballast.

Table 10 shows that payback period for T8 electronic system, HPT8 system and T5 system are from 10% to 100% retrofit. If retrofitting is fully done, can be seen that payback period for T8 electronic is only required 0.689 years to recover back all the investment because of the small amount of investment compare to the other alternative. Payback period for HPT8 is 1.24

Table 10
Payback period and life cycle cost based on retrofit.

Year	T8 electronic		HPT8		T5	
	PP (year)	LCC (RM)	PP (year)	LCC (RM)	PP (year)	LCC (RM)
2012	0.000	0	0.000	0	0.000	0
2013	0.818	922,582	1.485	768,691	2.332	669,676
2014	0.802	1,882,019	1.456	1,568,056	2.287	1,366,044
2015	0.787	2,879,463	1.428	2,399,088	2.242	2,089,998
2016	0.771	3,916,053	1.400	3,262,734	2.198	2,842,365
2017	0.756	4,992,955	1.372	4,159,967	2.155	3,623,990
2018	0.741	6,111,366	1.345	5,091,783	2.112	4,435,743
2019	0.727	7,272,517	1.319	6,059,209	2.071	5,278,516
2020	0.712	8,477,669	1.293	7,063,295	2.030	6,153,227
2021	0.698	9,728,119	1.268	8,105,120	1.991	7,060,814
2022	0.685	11,025,195	1.243	9,185,793	1.952	8,002,244

year since the cost for retrofit also slightly higher than T8 electronic. For the last alternative that is T5 system required 1.95 years to recover the initial investment due to cost for retrofitting is higher.

Life cycle cost (*LCC*) is the total cost of equipment, including cost of operation, and maintenance. The present worth factor using for calculating *LCC* was 5.795. The objective of *LCC* analysis is to choose the most cost effective approach from a series of alternatives to achieve the lowest long-term cost of ownership. Life cycle cost in Table 10 show that cost for installation and maintenance cost over the lifespan of the lighting system. The T8 standard system having a highest amount for *LCC* which is RM13,352,669. The *LCC* for T8 electronic RM11,025,195 reduce about 17% from existing system. For the second alternative, LCC for HPT8 system is RM9,185,793 reduce to 31% compared the existing system because the operating cost is higher. Life cycle cost for T5 system reduces RM8,002,244 up to 40% if 100% done, which is consider low cost compare to the standard and the other alternatives. This is due to the less in operating cost.

5. Conclusions

This studies estimate retrofitting about 10% per year for replacing the existing system. The energy analysis is not much effect if small amount of replacement have been made. Comparison done based on 100% retrofit of energy efficiency system more apparent. Among of the three alternatives that were studied, the result of the study found that, T5 system is suitable for retrofit system compare to T8 electronic and HPT8 system. This is because the energy consume by the T5 system reduce about half of the T8 standard system. By retrofitting the existing system with T5 system at 100% done, about 40% energy savings can be save in campus. However, T8 electronic and HPT8 system saved energy only 17% and 31% respectively compared to T8 standard system. By retrofitting to new T5 system, energy can be save about 40%. Using the T5 system will considerably improve the potential for energy saving in lighting installations. Even though cost for T5 system slightly higher than T8 electronic and HPT8 lighting system, it more cost saving in future. This is important because energy costs are rising every year. T5 system show more savings and cost benefits compared to high T8 electronic and HPT8. From the result of discussion show that, the two alternatives compared, T5 system take 1.95 years to recover spent in investment. It consider appropriate since cost for T5 system is higher than T8 electronic and HPT8. For the second alternative, LCC for HPT8 system is lower compared to the existing system because the operating cost is higher. Life cycle cost for T5 system is reduces to up 40% that is consider low cost compare to the standard and the other alternatives technology.

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